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Standard Terminology Relating to Iron Castings[1]

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This standard has been approved for use by agencies of the Department of Defense.

ausferrite, *n*—a cast iron matrix microstructure, produced by a controlled thermal process, which consists of predominantly acicular ferrite and high carbon austenite. (See **austempered ductile iron**.)

austempered ductile iron, *n*—a ductile cast iron that has been produced by a controlled thermal process which results in a matrix microstructure consisting of predominately acicular ferrite and high carbon austenite.

austenitize, *vt*—to convert the matrix of a ferrous alloy to austenite by heating above the transformation temperature.

batch, *n*—the component raw materials properly weighed, proportioned, and mixed for delivery to a processing unit. Also, the product output from a processing unit in which there is essentially no product output until all component materials are charged and processed.

brittle fracture, *n*—fracture that occurs without appreciable plastic deformation of the material.

brittle fracture area, *n*—The fraction or percent of the fracture surface that formed by brittle fracture. (When observed with no or low magnification, brittle fracture appears whiter and shinier than ductile fracture.)

capability index (C_p), *n*—for a stable process, the specification range divided by six times the standard deviation.

$$C_p = \frac{(USL - LSL)}{6 \times s}$$

capability index (C_{pk}), *n*—for a stable process, the smaller of the upper capability index (CPU) or the lower capability index (CPL).

carbide, primary, *n*—carbide precipitated in cast iron during solidification.

cast iron, *n*—a generic term for a series of alloys primarily of iron, carbon, and silicon in which the carbon is in excess of the amount which can be retained in solid solution in austenite at the eutectic temperature.

cementite, *n*—a very hard and brittle compound of iron and carbon corresponding to the empirical formula Fe_3C, commonly known as iron carbide.

cementite, primary, *n*—cementite precipitated in cast iron during solidification. Also known as primary carbide. (See **cementite**.)

chill, *n*—an object, usually metal, imbedded in a portion of the mold to accelerate the local rate of heat removal from the metal being cast.

chill, *v*—to accelerate the freezing rate of cast iron, usually in a localized region, to refine the graphite structure or cause formation of primary carbides.

chill, microstructural, *n*—a localized region of primary carbides in a casting made from a cast iron that would normally solidify free of primary carbides.

chilled iron, *n*—a cast iron that would normally solidify free of primary carbide which is purposely caused to solidify as white cast iron, locally or entirely, by accelerated cooling.

compacted graphite iron, *n*—a cast iron that has been treated in the liquid state so as to cause its graphitic carbon to occur in the compacted graphite shape in the as-cast condition. (See **graphite, compacted** and **graphite, spheroidal**.)

confidence level, *n*—the probability, or expected percent of the times, that the selected percent (P %) of the actual population lies within the tolerance interval calculated from the data sample.

direct reduced iron, *n*—iron ores that have been reduced to essentially metallic iron by heat and reducing agents, but without melting, and processed into suitable shapes (typically pellets) for use as a charge material in a melting operation.

dual metal, *n*—two metals of different composition that are fusion bonded at all interfacial surfaces by casting metal of one composition against metal of a second composition.

ductile fracture, *n*—fracture that occurs with appreciable plastic deformation of the material.

ductile fracture area, *n*—The fraction or percent of the fracture surface that formed by ductile fracture. (When observed with no or low magnification, ductile fracture appears grayer and duller than brittle fracture.)

ductile iron, *n*—a cast iron that has been treated in the liquid state so as to cause substantially all of its graphitic carbon to occur as spheroids or nodules in the as-cast condition.

[1] This terminology is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.91 on Editorial Matters and Nomenclature.

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ferritize, *vt*—to increase the quantity of ferrite in the matrix of a ferrous casting through an appropriate heat treatment.

ferritizing anneal, *n*—the process of producing a predominantly ferritic matrix in cast iron through an appropriate heat treatment.

graphite, compacted, *n*—a graphite shape that is intermediate between flake graphite and nodular graphite that typically appears in a polished section as thick flakes with blunt (compacted) ends.

graphite flake, *n*—an irregularly shaped particle of graphite, usually appearing in a polished section as curved plates, such as found in gray cast irons.

graphite, nodular, *n*—spheroidal shaped graphite typically found in ductile irons and compact clusters of graphite typically found in malleable irons. (See **graphite, spheroidal**, and **temper carbon**.)

graphite, primary, *n*—graphite precipitated in cast iron during solidification.

graphite rosette, *n*—arrangement of graphite flakes in which the flakes extend radially from centers of crystallization in gray cast iron.

graphite, spheroidal, *n*—spheroidal shaped graphite having a polycrystalline radial structure, usually found in ductile iron and to a controlled, limited extent in compacted graphite iron.

graphitize, *vt*—to precipitate graphite in an iron-carbon alloy.

gray iron, *n*—cast iron that has a relatively large proportion of the graphitic carbon present in the form of flake graphite. The metal has a gray fracture.

heat, *n*—the total molten metal output from a single heating in a batch melting process or the total molten metal output from essentially a single heating in a continuous melting operation using basically constant charge and processing conditions and targeted at a fixed metal chemistry at the furnace spout. A heat can also be defined as a fixed time period for a continuous melting operation provided that it is shorter than the time period covered by the above definition.

inoculated iron, *n*—cast iron, either liquid or solid, to which one or more inoculating alloys have been added while the iron was in the molten state.

inoculated iron, fully, *n*—cast iron, either liquid or solid, to which all molten metal additions, including all inoculating alloys, have been added.

inoculating alloy, *n*—an alloy added to molten iron for the principle purpose of nucleating a primary phase such as graphite. Inoculating alloys are frequently used to avoid the formation of primary carbide by enhancing the nucleation of graphite.

lot, *n*—a finite quantity of a given product manufactured under production conditions that are considered uniform.

lower capability index (CPL), *n*—the difference between the sample mean ($\bar{x}$) and the lower specification limit divided by three times the standard deviation.

$$CPL = \frac{(\bar{x} - LSL)}{3 \times s}$$

lower specification limit (LSL), *n*—the lowest specified value.

M, *n*—the number of standard deviations, mutually concurred by the supplier and purchaser, to be used for calculations of statistical conformance to such items as minimums, maximums, specification ranges, and process capability indices.

DISCUSSION—*M* values of three or less were used in establishing initial ASTM specification limits; higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides; in the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

malleable, ferritic, *n*—a ferrous alloy that is cast as white iron but which is converted by an appropriate heat treatment to a microstructure of temper carbon embedded in a ferritic matrix essentially free of pearlite and carbide.

malleable iron, *n*—a cast iron of such composition that it solidifies as white iron, which upon proper heat treatment is converted to a metallic matrix with nodules of temper carbon.

malleable, pearlitic, *n*—a ferrous alloy that is cast as white iron but which is converted by an appropriate heat treatment to a microstructure of temper carbon embedded in a matrix containing a controlled quantity, form, and distribution of pearlite or tempered martensite.

malleableize, *vt*—to convert white iron into malleable iron through an appropriate graphitizing heat treatment.

maximum (non-statistical), *n*—the highest acceptable actual test result; any valid individual test result above the maximum is cause for rejection of the component or material lot being tested.

$$\text{All } x_i \leq \text{Maximum} = USL$$

maximum (statistical), *n*—the highest acceptable statistical test result; for compliance, the sample mean ($\bar{x}$) plus *M* standard deviations(s), where *M* is a matter of agreement between the supplier and purchaser, must be less than, or equal to, the upper specification limit.

$$\bar{x} + M \times s \leq \text{Maximum} = USL$$

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2— *M* values of three or less were used in establishing initial ASTM specifications limits. Higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides. In the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

mean ($\bar{x}$), *n*—the sum of the individual data points (*x*'s) divided by the number of data points (*n*).

$$\bar{x} = \frac{\Sigma x_i}{n}$$

melt, *n*—the total molten metal produced in a single heat.

merchant pig iron, *n*—pig iron produced for commercial sale to foundries.

minimum (non-statistical), *n*—the lowest acceptable actual test result; any valid individual test result below the minimum is cause for rejection of the component or material lot being tested.

$$\text{All } x_i \geq \text{Minimum} = LSL$$

minimum (statistical), *n*—the lowest acceptable statistical test result; for compliance, the sample mean ($\bar{x}$) minus *M* standard deviation(s), where *M* is a matter of agreement between the supplier and purchaser, must be greater than, or equal to, the lower specification limit (LSL).

$$\bar{x} - M \times s \geq \text{Minimum} = LSL$$

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2—M values of three or less were used in establishing initial ASTM specification limits; higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides; in the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

mottled iron, *n*—a cast iron containing a mixed structure of gray iron and white iron of variable proportions. The fracture has a mottled appearance.

nodular graphite, *n*—graphite in the form of nodules or spheroids in iron castings.

nodularity, *n*—the volumetric proportion of spheroidal or nodular graphite to total graphite in a ductile iron or a compacted graphite iron matrix (see Test Method A 247, for Evaluating the Microstructure of Graphite in Iron Castings,[2] Types I and II).

nodularity, degree of, *n*—the volumetric proportion of spheroidal or nodular graphite to total graphite in a ductile iron matrix (see Test Method A 247, Types I and II).

nodulizing alloy, *n*—an alloy added to molten iron for the primary purpose of causing the formation of spheroidal graphite during solidification.

pig iron, *n*—the high carbon iron product obtained by the reduction of iron ores, typically in a blast furnace or an electric furnace, and cast into uniform shapes (pigs) having physical and chemical characteristics suitable for end use as foundry melting stock.

range, data, *n*—the absolute value of the difference between the highest and lowest values in a set of data.

range, specification (non-statistical), *n*—the absolute value of the difference between the highest (USL) and lowest (LSL) specified values; for compliance with a non-statistical range, each valid individual test result must lie at, or within, the specification limits.

$$LSL \leq \text{All } x_i \leq USL$$

range, specification (statistical), *n*—the absolute value of the difference between the highest (USL) and lowest (LSL) specified values; for compliance with a statistical range, all calculated values from the mean ($\bar{x}$) minus *M* times the standard deviation(s) to the mean plus *M* times the standard deviation, where *M* is a matter of agreement between the supplier and purchaser, must not lie outside of the specification limits.

$$LSL \leq \bar{x} - M \times s \quad \text{and} \quad \bar{x} + M \times s \leq USL$$

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2—*M* values of three or less were used in establishing initial ASTM specification limits; higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides; in the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

sample, *n*—one or more portions of a liquid or solid material taken in an unbiased manner from a batch, heat, lot, or process stream to be representative of the whole, for subsequent testing to determine the chemical, physical, mechanical, or other quality characteristics of the material, or combination thereof.

standard deviation (*s*), *n*—a measure of the dispersion of a series of results around their average, expressed as the square root of the quantity obtained by summing the squares of the deviations from the average of the results and dividing by the number of observations minus one; it is also the square root of the variance and is calculated as follows:

$$s = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{(n-1)}}$$

where:

s = estimated standard deviation of the series of results,
x_i = each individual value,
$\bar{x}$ = mean (average) of all values, and
n = number of values.

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2—It is desirable to use at least 30 data points to calculate the sample mean. The use of smaller sample sizes results in reduced confidence in the estimated value of the standard deviation.

steel scrap, *n*—discarded steel or steel products, generally segregated by composition and size or ''grade,'' suitable for melting.

temper carbon, *n*—compact aggregates or nodules of graphite found in malleable iron as a result of heat treatment.

test bar, *n*—a bar-shaped coupon that is tested with or without subsequent preparation for the determination of physical or mechanical properties.

test coupon, *n*—specially designed casting, or portion thereof, that is used to provide a representative sample of the iron from which it was cast.

test lug, *n*—a sample produced as an appendage on a casting, that may be removed and tested to qualify the casting or the iron from which it was produced.

test specimen, *n*—a test object, suitably prepared from a sample, for evaluation of the chemical, physical, mechanical, or metallurgical quality of the sample.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

tolerance interval, *n*—a range constructed from an experimental data sample so as to statistically enclose P % or more of the population from which the sample was drawn with a confidence level of 100 (1−α) %.

DISCUSSION—As an example, for data from a population with a normal distribution, $\bar{x} \pm K \times s$ will statistically bracket P % or more of the population with confidence 100 (1−α) % where K is a function of the sample size (*n*), P, and α in statistical tables of tolerance factors (K) for population proportion (P) of normal distributions. Upper (U) or lower (L) one-sided tolerance limits can be calculated from $U = \bar{x} + K \times s$ or $L = \bar{x} - K \times s$ such that statistically, P % or more of the population lies below U or above L with confidence 100 (1−α) %. If the data is not from a population with a normal distribution, different tables or approaches, or both, need to be used.

transition temperature, *n*—the test temperature for which the fracture surface of the test specimen shows 50 % ductile and 50 % brittle fracture.

treated iron, *n*—molten cast iron to which all basic alloys and nodulizing alloys have been added but not necessarily all inoculating alloy additions.

upper capability index (CPU), *n*—the difference between the upper specification limit and the sample mean divided by three times the sample standard deviation.

$$CPU = \frac{(USL - \bar{x})}{3 \times s}$$

upper specification limit (USL), *n*—the highest specified value.

white iron, *n*—cast iron in which substantially all of the carbon is in solution and in the combined form. The metal has a white fracture.